Nota Lepi. **48** 2025: 1–14 | DOI 10.3897/nl.48.126042 Research Article

Sufetula culshawi sp. nov. (Lepidoptera, Crambidae, Lathrotelinae): a previously unrecognised species affecting cultivated palms

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https://zoobank.org/468080E7-E4CE-470F-9A6F-707DB94162A5

Received 23 April 2024; accepted 13 December 2024; published: 3 January 2025
Subject Editor: Théo Léger.

Abstract. A new species of the pantropical genus *Sufetula* Walker, 1859 (Crambidae: Lathrotelinae) is described. A male specimen was found by Martin Culshaw as an accidental import in Stirlingshire, Scotland, whilst a female specimen was later found in the Natural History Museum collections, which had been reared in southernmost Kyushu, at Ibusuki, Japan. These specimens do not match externally the 31 currently accepted described species in the genus. We obtained a full 658 bp DNA barcode from both specimens (together with all of COI from the Japanese exemplar) that confirmed their conspecificity but showing at least 7.49% p-distance from any presently existing cluster. Phylogenetic analysis, including 14 other exemplars with DNA barcodes from BOLD/GenBank, failed to place the new taxon with any existing lathroteline species group. The Japanese specimen was reared from the roots of an Areca Palm *Chrysalidocarpus lutescens* Wendland in 1987, whilst the specimen imported to Scotland may have emerged from the same species. This information suggests that the new species is a previously unrecognised coloniser of horticulturally imported palms. Currently we cannot rule out the hypothesis that the species is native to habitats containing palms in the southern Japanese islands, and further specimens should be searched for in collections and in the wild. However, INaturalist images externally diagnostic for the species suggest it is widespread in South East Asia.

Introduction

Lathrotelinae Clarke, 1971 (originally instated as a family based on *Lathroteles obscura* Clarke, 1971) was recently rehabilitated on a morphological basis as a subfamily of Crambidae, based on minute tympanic organs at the edge of sternum A2 (Minet 2015). The subfamily is characterised by absence of chaetosemata, complete reduction of the gnathos, and a phallus distally with a strongly spiculose "manica" (Hayden 2013; Minet 2015). *Diplopseustis* Meyrick, 1884, *Diplopseustoides* Guillermet, 2013 and *Sufetula* Walker, 1959 were recognised as morphologically related genera within the subfamily. Further molecular work suggested that Lathrotelinae is the sister group of the fern-feeding subfamily Musotiminae (Léger et al. 2021). Lathrotelines, instead, are known to be specialists on monocotyledons and some species feed on palms (Arecaceae) (Genty and Mariau

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1975). The subfamily in addition contains the genera *Acropentias* Meyrick, 1890 and *Orthoraphis* Hampson, 1896 (Nuss et al. 2023). In Britain, only *Diplopseustis perieresalis* (Walker, 1859) has hitherto been reported as an adventive, with at least 37 British records since 2001 (Mackay and Fray 2002; Parsons and Clancy 2023), while in Europe, two species of the pantropical genus *Sufetula* (*S. diminutalis* [Walker, 1859] and *S. boileauae* Nel, 2022) have been reported (Lepiforum 2024). This last species was described as new from a specimen imported on a Malagasy palm originating in Honduras (*Chrysalidocarpus lutescens* Wendland) and found in 2021 in Haute Garonne, France (Nel 2022). *Sufetula* is a large genus currently comprising 31 described species (Nuss et al. 2023).

More recently in the United Kingdom (on 12 July 2022), Martin Culshaw discovered a small micromoth resting on an inside wall in his house in Killearn, Stirlingshire (VC86), Scotland. This male specimen did not appear to match *D. perieresalis* and rather appeared to represent a species of *Sufetula*, a genus not previously reported from Britain. We subsequently discovered a conspecific female specimen in NHMUK from Japan. Here we detail the process of elimination and morphological and molecular analysis, which enables us to describe another new species to science.

Abbreviations

BIN = Barcode Index Number; **BOLD** = Barcode of Life Database; **fwl** = forewing length; **NHMUK** = Natural History Museum; **HUS** = Hokkaido University, Sapporo; **OU** = Hope Department of Entomology, Oxford University.

Methods and materials

Process of identification by elimination

The moth found in Scotland by Martin Culshaw (MC) was caught for closer examination and identification. It was apparent that it had emerged from a houseplant, most likely an Areca Palm *Chrysalidocarpus lutescens* bought from a local nursery in May 2022 but originating from a nursery in the Netherlands.

Suspecting that it was an imported species, MC uploaded two photographs of the live male to the Scottish Moths online forum (https://groups.io/g/scottishmoths/message/6260) on 12 July 2022 (Figs 1c, 2a), asking if anyone recognised it. NR suggested that it resembled a species of the genus *Sufetula*. Others suggested a species of *Diplopseustis* such as *D. perieresalis*, and certainly that it belonged to the subfamily Lathrotelinae. Enquiries by MY to British and European microlepidopterists and by NR to American experts confirmed it as a member of *Sufetula*, without species-level determination. James Hayden (pers. comm. to NR) considered provisionally the maculation as consistent with *S. diminutalis*, but that dissection was required to confirm this. PH dissected the genitalia (whilst the rest of the specimen was relaxed and mounted then passed via MY to DL at NHMUK), and the slide was later passed to DL who compared images of the adult and dissection with the collection in NHMUK, but it did not match individuals of *S. diminutalis*. PH enquired of Théo Léger and Anne Müller in MfN (Berlin) whether it might match any of the Lathrotelinae of the Philippines, which they have been revising. Léger noted recent records of *Sufetula* in Iceland and France. The Iceland example is clearly different from the Scottish one (Ole Karsholt pers. comm. to PH). Jacques Nel (pers. comm.) confirmed that *S. boileauae* Nel, 2022 from France is not conspecific with the Scottish specimen. No clearly matching images were found initially in an online search by PH in 2022. With wing pattern and male genital morphology failing to provide a

clear match, MY dispatched a leg to DL at NHMUK for analysis via DNA barcoding, and PH later provided the rest of the specimen. DL compared the mystery specimen to type and other material at NHMUK (see Other material examined and Remarks).

Following our exhaustive efforts to determine the male moth found in Scotland, including the lack of a close species match in the DNA barcoding results, and consultation with experts on the group, we concluded that it represented an undescribed species. Thereafter, a conspecific female was discovered by DL in the Inoue accessions at NHMUK from Japan. This correspondence was initially based on morphological similarity but then confirmed by DNA analysis (see below). Here we describe a new species of *Sufetula*, based on these two specimens. Finally, DL re-examined images on INaturalist in November 2024 for potential matches externally diagnostic for the species.

Morphological methods

The specimens NHMUK013699321 (from Scotland) and NHMUK013706270 (from Japan) were photographed using a Canon EOS 5D SR camera with MP-E 65 mm lens equipped with a Stackshot system operated by Helicon Remote software (version 3.8.4 W) controlling a customised motorised platform and the specimens illuminated with four customised natural white LED light sources. Stacking was carried out by montaging 35–60 individual photographs using Helicon Focus software (version 6.7.1) (Fig. 1a, b, d).

The abdomen of the holotype female (NHMUK013706270) was dissected by DL after return from proteinase K lysis (see below) with further maceration using 10% KOH, then transfer to 50% ethanol. The abdomen was opened from one side, the genitalia separated, stained with a drop of Chlorozal black, and the abdomen flattened out and cleaned with a snipe feather, and then both parts separately mounted in a small drop of Euparal, which was allowed to settle for two hours before extra Euparal was added with each coverslip. The abdomen of the male paratype (NHMUK013699321) was dissected by PH. It was macerated using 10% KOH and then opened up and flattened under a cover slip together with a drop of pure water and then left to dry out. The male genitalia were then gently removed and immersed in clove oil for clearing. Once clear of air bubbles they were further transferred into a drop of fresh clove oil on a new slide, and then re-covered with a cover slip for interim photography. The images were created using a Nikon D90 DSLR camera body mounted onto a Nikon Eclipse E55i compound microscope. This was followed by focus stacking using Helicon Focus v8 before finishing off with Photoshop Elements v7. The resulting montage was cleaned up and the background standardised. Following this procedure, the structures were then transferred to a new slide using Euparal as a mountant for permanent preparation. All photographs and figures were finally manipulated and the dissection images colour-balanced using Adobe Photoshop 25.5.0.

Morphological terminology follows Kristensen (2003).

Molecular methods

After standard extraction, using primers for Sanger sequencing (see Sterling et al. 2023a for details) the DNA barcode for the Scottish specimen was generated single stranded, using Oxford Nanopore Technologies (ONT) SQK-LSK110 ligation kit and a 200-pore ONT Flongle flow cell (R9.4.1, FLo-FLG001) fitted to a GridIoN X5 benchtop sequencing machine, with assembly done using ONTbarcoder software, as also documented in Sterling et al. (2023a). Similar methods failed, however, to provide a DNA barcode for the Japanese specimen, either from a single leg or from the entire abdomen lysed in Proteinase K. A further leg was then subjected to "genome skimming", as described for the ancient DNA protocol in Sterling et al. (2023b), except that bioinformatic assembly was done on a cluster.

For comparison with the DNA barcode obtained at NHMUK from the Scottish male and the Japanese female, we downloaded representative sequences of Lathrotelinae that were publicly available with GenBank accession numbers, out of a total (1/12/2023) on BOLD of 130 DNA barcoded specimens belonging the Lathrotelinae, comprising 12 BINs, with nine named species in public data. At least nine BINs belonged to the genus *Sufetula* and three to the genus *Diplopseustis*. Sixteen DNA barcodes, including that from the Scottish male and 1441 bp from the entire COI region of the Japanese female (Suppl. material 1), were aligned using MAFFT (https://mafft.cbrc.jp/alignment/server/index.html) in fasta format and gaps removed manually in Bioedit v. 7.2.5 (Hall 1999). In order to include more phylogenetic information, the three sample vouchers on GenBank (see Leger et al. 2021) or BOLD, that include the COI-3P part of COI, *S. diminutalis* (accession MK459668); *S.* cf. *sythoffi* (Snellen, 1899) (voucher ZMBN57, accessions LR743383, LR743406), and *D. perieresalis* (voucher ZMBN68, accessions LR743382, LR743405) were integrated into the analysis with the whole of COI of *Musotima nitidalis* (Walker, 1866) (OX421444.1; Sterling et al. 2024). This dataset was analysed using Phyml 3.0 online (http://www.atgc-montpellier.fr/phyml). The ML model selected automatically (using the Akaike Information Criterion option) was "GTR +G". The resulting tree file was visualised in FigTree v. 1.4.3 (http://tree.bio.ed.ac.uk/software/figtree/), rooted with *Musotima nitidalis* (Walker) (Musotiminae). Bioedit v. 7.2.5 was used for checking pairwise divergences (Pairwise Alignment. Calculate Identity/Similarity) by converting to percentages between pairs of sequences. By using the 'Conservation Plot' option in Bioedit (Fig. 2b), to the outgroup *Musotima nitidalis* as the reference sequence, we visualised potentially informative codon changes by switching to amino acid display, alongside downloaded DNA barcodes from BOLD. This was used to confirm that the query sequence belonged to Lathrotelinae and to check for potential synapomorphies.

The DNA barcodes for specimens NHMUK013699321 and NHMUK013706270 are publicly available with GenBank accession numbers PP391030 and PQ458043, respectively, and also on BOLD (Process IDs UKMOT012-24, UKMOT017-24; BIN, BOLD:ADV8747; uri: https://v4.boldsystems.org/index.php/MAS_Management_DataConsole?codes=DS-SUFETULA).

Molecular results

Querying the sequence from the Scottish specimen on BOLD (http://v4.boldsystems.org/index.php) on 1/12/2023, the DNA barcode was 7.49% p-distant with most similar sequences in Erebidae, while the nearest crambid (not a lathroteline) was 7.8% p-distant. Building the Neighbor Joining tree, the nearest neighbour was connected by a long branch but also unrelated: (*Mixodetis* South Australia|Scythrididae). No Lathrotelinae came up in the top 100 hits. This led us to do a more detailed analysis on the DNA barcode obtained.

A contamination was ruled out by analysis of the 1527 bp COI sequence later assembled from the Japanese female (with 27 ambiguous base calls in the COI-3P region), which was just 1 bp different among 658 bp in COI-5P (although leading to one amino acid difference, a Serine not Proline in the 116th codon; Fig. 2b). Phylogenetic analysis of these data (Phyml 3.0; Fig. 2a) also confirms that the DNA barcode does indeed belong to *Sufetula* and not *Diplopseustis*. This is the case assuming that "*Diplopseustis*" sp. "ANIC1" (BOLD:AAO6767) (Fig. 2a) represents a misidentification, actually being a species of *Sufetula*. This along with COI of the query taxon (BOLD:ADV8747) and representatives of six other BIN clusters analysed (BOLD:ACQ0790, BOLD:AAU7538, BOLD:AEN1892, BOLD:AAE2660, BOLD:AAM8245, BOLD:AAO8938) show support (pp = 0.99) for this concept of *Sufetula* as a clade. This grouping includes a DNA

barcode identified on BOLD as *S. diminutalis* (BOLD:AAE2660), which was re-identified by Léger et al. (2021) as *S.* cf. *sythoffi*. Three other taxa on BOLD represented by only short sequences that are more than 10 percent pairwise divergent from our query sequence, *S. sunidesalis* (Walker, 1863) (Process ID LNAUW3158-17, from the Philippines), *S. sacchari* (Seín, 1930) (Process ID LNAUW3159-17, from Puerto Rico) and *Sufetula* sp. (Process ID LNAUW3160-17, from Papua New Guinea), are not included in the analysis. Nor was *S. boileauae* (BOLD:ADR5494), whose BIN is only 2.4% p-distant from *Sufetula* "*diminutalis*" (BOLD:ACQ0790).

Since the precise position of the Scottish specimen is not firmly supported (Fig. 2a), we considered the translated DNA barcodes in more detail (Fig. 2b). Apart from the possible misidentifications to genus (the taxa representing BINs BOLD:AAO6767 and BOLD:AAO9849, both from Australia), all *Diplopseustis* species exhibit the state Methionine (M) in the 88th complete codon of the DNA barcode (Fig. 2b). Whilst not shown here, a DNA barcode identified on BOLD as *Lathroteles* sp. (BOLD:ADL9526, PMANL5721-17, USNMENT01374199, from French Polynesia) clearly fits with *Diplopseustis* in terms of its character states. All analysed members of the *Sufetula* 'clade' (pp = 0.99 in Fig. 2a) exhibit a Leucine (L) rather than the state of Valine (V) [or Isoleucine (I)] in complete DNA barcode position 13 (Fig. 2b). An Isoleucine rather than Valine for a smaller set of *Sufetula* not including the mystery species is shown in the 169th complete codon. Finally, the combination of a Serine (S) rather than Phenylananine (F) in the 30th complete codon and an Asparagine (N) rather than Guanine (G) in the 159th complete codon is shown for the Neotropical *S. diminutalis* species complex. The tree shown in Fig. 2a also shows that the mystery species does not in fact belong to the last complex (pp = 1; Fig. 2a), a grouping comprising the BINs BOLD:AAU7538 from French Guiana, BOLD:AEN1892 from Panama, BOLD:ACQ0790 recorded from United States and Germany and BOLD:AAH5889 from Costa Rica and Honduras; the last BIN seems a strong candidate to represent the 'true' *S. diminutalis*, for which the last country is the type locality. Meanwhile, "*Diplopseustis*" *prophetica* Meyrick, 1887 (BOLD:AAO9849, Process ID ANICN120-10, accession HQ952545) represents an outlier in its wing pattern (e.g. it lacks the white costal triangles on the forewing found in *Sufetula* and *Diplopseustis*) and in its distribution of molecular character states; it is not included in any of the other lathroteline groupings based on COI (Fig. 2a) and likely it belongs to a different genus.

Although the DNA barcode from the Scottish moth is 12.2% pairwise divergent from *S.* cf. *sythoffi* (BOLD:AEG2660), there are only five amino acid differences between them (Fig. 2b); *S. alychnopa* (Turner, 1908) (BOLD:AA08938, Process ID ANICN113-10) is 11.85% pairwise divergent, also with the same number of amino acid differences (Fig. 2b); it is 11% pairwise divergent across 610 shared bp to "*Diplopseustis*" sp. (BOLD:AAO6767), the taxon most closely adjacent to our species in the tree.

Taxonomy

Sufetula culshawi, sp. nov.

https://zoobank.org/290B0AF9-06A4-4A2A-878B-66392E54D2EC

Figs 1a–d, 2a, 3a–e

Material examined. Type material. ***Holotype*:** NHMUK013706270|"Holo-type"|"Ibusuki Kagosima Kyusyu 13.XI.1987 M. Kobayashi"| "Host アレカヤシ　の新根" [Host Arekayashi/Areca Palm new roots of]|*Sufetula culshawi* sp. nov. Holotype ♀|Brit. Mus 1988-80"|Slide no. NHMUK 014332671; Paratype: NHMUK013699321| "Para-type"|"UNITED

KINGDOM, Scotland, Killearn, Stirlingshire, VC86, NS504852, 12.vii.2022."| "*Sufetula culshawi* sp. nov. Paratype ♂". Accidental import probably from *Chrysalidocarpus lutescens* palm. Leg. M. Culshaw"|Slide no. NHMUK014331873.

Diagnosis. A comprehensive differential diagnosis is beyond the scope of this paper as it would necessitate a full revision of the genus. However, a combination of four superficial characters appears to be diagnostic for *S. culshawi*, when compared to other described species (see Other material examined, and Remarks).

First, comparing both Scottish and Japanese specimens to other members of *Sufetula*, the rather uniform greyish forewing pattern distinguishes this species, whilst most other species show a ground pattern relatively more marbled with dark scaling. Second, the broad and relatively straight white, internally black, hindwing fascia appears distinctive ("*Diplopseustis*" sp. BOLD:AAO6767 has such a straight median hindwing fascia but lacks the broad white internal band: Fig. 2a). Third, the right angled fascia below M2 in the forewing that meets perpendicularly to the tergum is one of the more distinctive features of *S. culshawi* (in *S. sunidesalis*, for example, the forewing postdiscal white fascia, rather, curves distad again to meet the tergum; see other configurations in Fig. 2a). Fourth, there is a marked distinction between a white bar on A2 dorsum (Fig. 1c; Fig. 1d, where visible although worn) and the otherwise darker grey abdomen is accentuated by the black basal hindwing area/fascia and whitish median fascia of the hindwing, when *S. culshawi* is at rest (Figs 1c, 2a). This white tergum A2 is not unique, though,

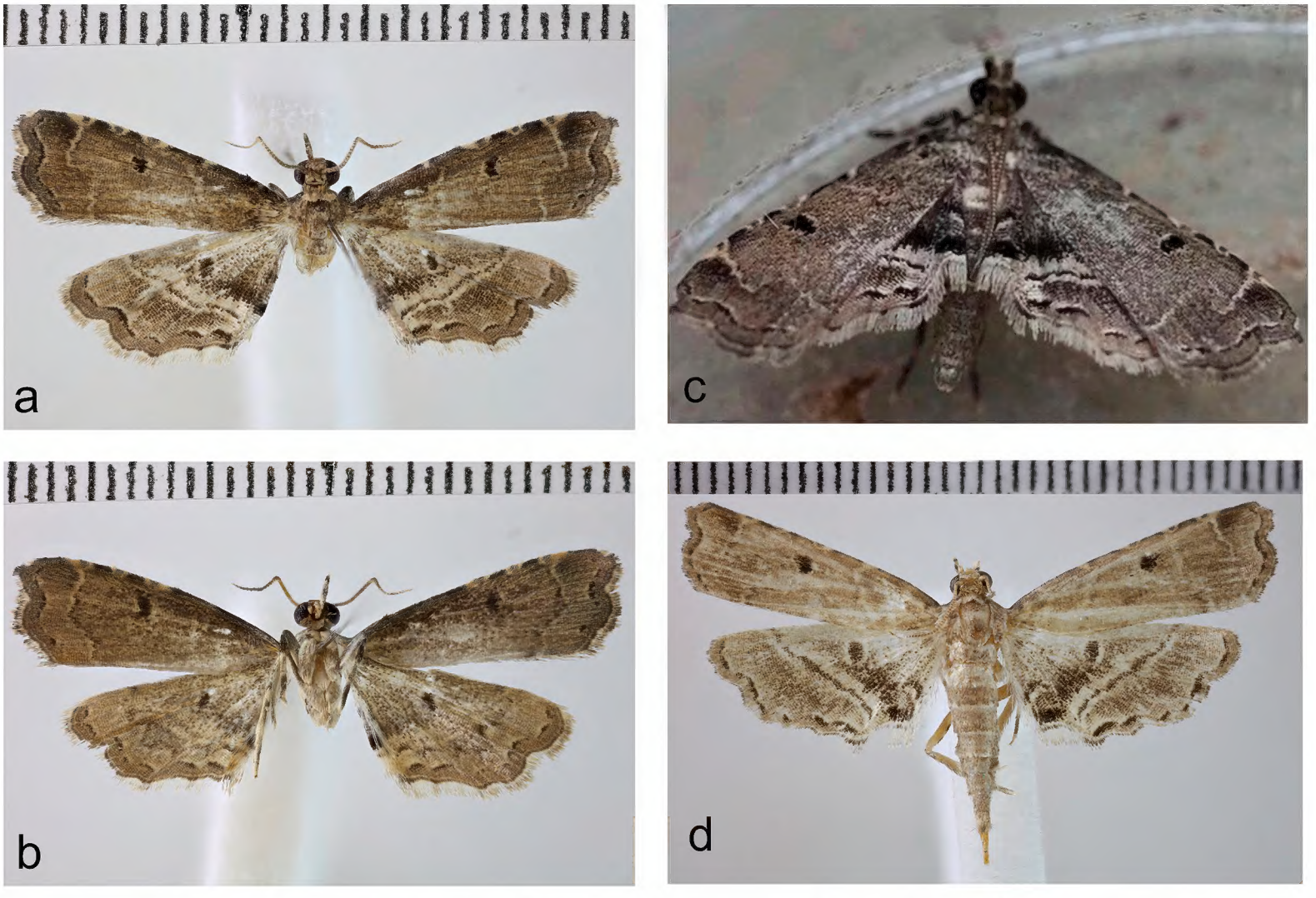


Figure 1. a. Dorsal view of *Sufetula culshawi* paratype male NHMUK013699321 from Stirling, Scotland; **b.** Ventral view of *S. culshawi* paratype male; **c.** *S. culshawi* paratype male habitus photo; **d.** *S. culshawi* holotype female NHMUK013706270 from Ibusuki, Japan, dorsal view.

to *S. culshawi*; it recurs in *S. diminutalis* and the type specimen of *S. sunidesalis* (https://oumnh.ox.ac.uk/collections-online#/item/oum-catalogue-3160).

Other possibly diagnostic characters were not assessed widely among species. The species is rather larger at least than members of the *S. diminutalis* group (Walker's type specimen of *S. diminutalis*, NHMUK013699687, measures 6.5 mm in forewing length). On the head, ocelli are present, unlike in *S. diminutalis* (Hayden 2013). The genitalia are likely to be diagnostic, but this awaits dissection of a larger range of species. For example, the uncus of *S. diminutalis* is relatively longer, its valves longer and thinner, and its juxta different (Hayden 2013: fig. 26). The extent of the two scobinate areas on the female bursa is likely diagnostic. Finally, at the base of the tympana, the posterior depressions of the male (Fig. 3c) are typical of the sexually dimorphic condition where they are invaginated in the female as in *S. carbonalis* and *S. diminutalis* (Hayden 2013: figs 18, 21; J. Hayden, pers. comm.), but the utility of this character also remains to be investigated among a wider range of species.

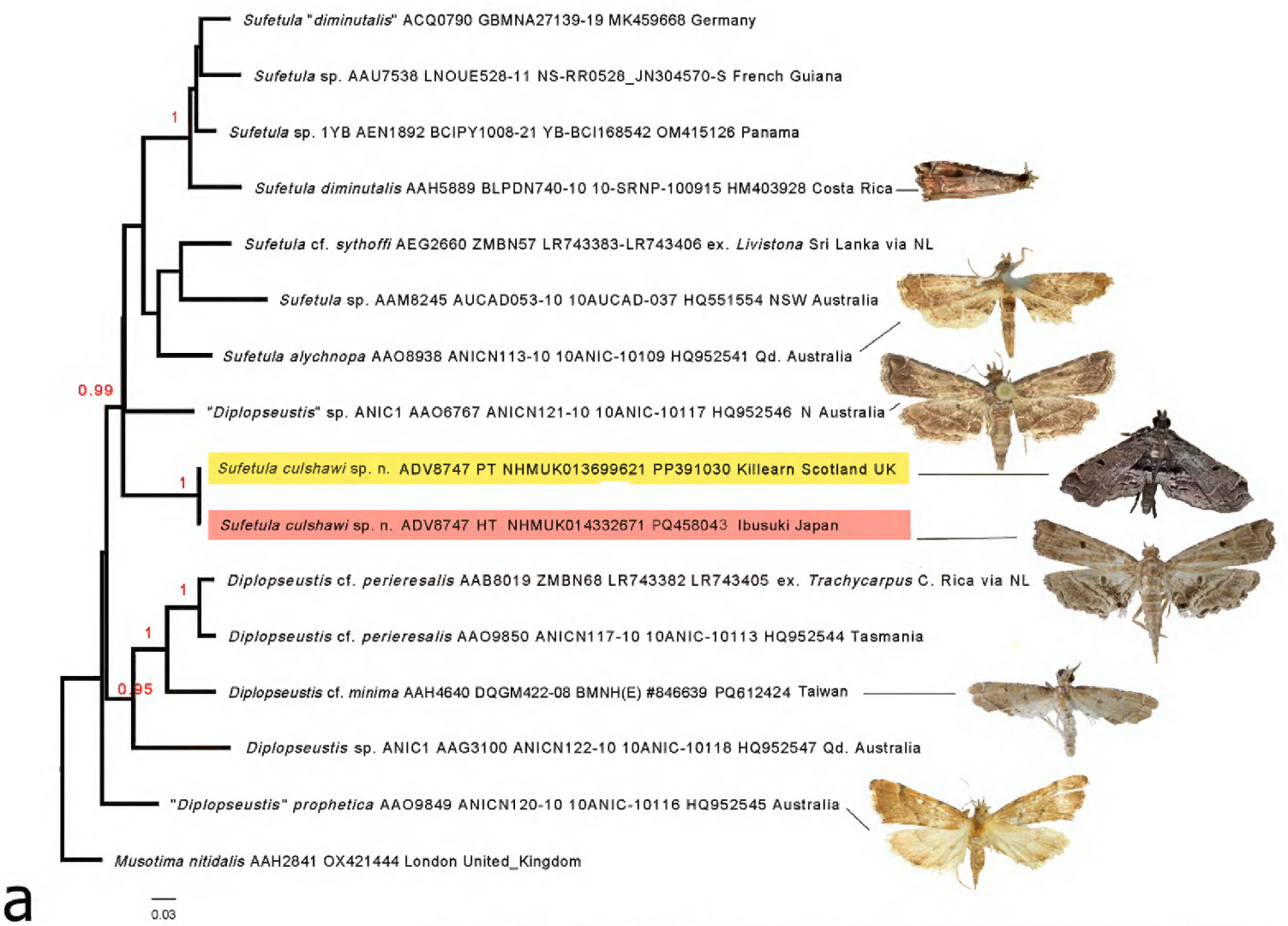
Description. ***Wingspan.*** c. 14.75–16.2 mm (apex to apex), fwl 7–8.5 mm.

Head. Compound eyes normal for genus, ocelli present, between pale scale tufts, chaetosemata absent. Frons with pale scales directed forward. Maxillary palp arising above labial palp and about 2/3 its length, with pale fawn scales on outer face, alternately banded. Labial palp mainly covered with paler scales on inner face and mainly darker ones on outer face, pale fawn at the tip of the third meron. Basal segment relatively short, curving up from head; second and third segments porrect, extended well beyond head (about diameter of compound eye). Second segment ventrally with forward-directed tuft of fawn and darker scales. Haustellum light fawn scaled, well-developed. Antenna almost half length of forewing (male). Antennal scape and pedicel unmodified, dark scaled. Flagellum with two rows of scales per flagellomere, flagellomere count around 31 (male) to at least 40 (in female), tapering towards tip, strongly ciliate. Flagellomeres darker basally, paler distally, ventral surface flattened and more uniformly brown.

Thorax. dorsal side dark grey-brown (male), fawn scaled in female. Crown (collar) with long cream scales, contrasting with background, laterally overlain by darker grey scales which are pale tipped. Patagia with uniformly dark scales. Tegulae brown scaled, with pale tips with a few darker scales distad.

Legs. Femur of foreleg pale ochreous underneath with mostly darker scales on outer surface, epiphysis present. Femur of mid leg similarly pale ochreous, tibia with two long unequal spines with black ring before pale tip, tarsal segments ochreous above and dark basally but whitish distally. Hindleg uniformly pale fawn on underside, distal half dark scaled in both dorsal tibia and tarsus, inner spur 1.5 times length outer spur, both with distal dark scales on dorsal surface (female); see also habitus photo of male (Fig. 1c).

Wings. (Largely based on freshly scaled male). Apex falcate. Forewing background colour composed rather uniformly of grey-brown scales. Premedian paler fascia indistinct, bent acutely near costa. Postmedian pale fascia bent inwards at right angle below M_3, then perpendicular to tergal edge of forewing. Submarginal pale line with dark distal border in shape shadowing termen, which is concave or strongly indented between M_1 and M_2. Discal black spot at 2/3 large and somewhat crescentic with pale border. Three v-shaped pale marks from level of discal spot to post median line along costa, enclosing dark grey triangles, and interspersed with blackish scales that are prevalent along costa; pale mark on costa at 1/3. White mark just before apex. One hindwing frenular bristle (both sexes). Hindwing at least as broad as forewing but more quadrate. Hindwing about 5.7


Sufetula "diminutalis" ACQ0790 GBMNA27139-19 MK459668 Germany
Sufetula sp. AAU7538 LNOUE528-11 NS-RR0528_JN304570-S French Guiana
Sufetula sp. 1YB AEN1892 BCIPY1008-21 YB-BCI168542 OM415126 Panama
Sufetula diminutalis AAH5889 BLPDN740-10 10-SRNP-100915 HM403928 Costa Rica
Sufetula cf. sythoffi AEG2660 ZMBN57 LR743383-LR743406 ex. Livistona Sri Lanka via NL
Sufetula sp. AAM8245 AUCAD053-10 10AUCAD-037 HQ551554 NSW Australia
Sufetula alychnopa AAO8938 ANICN113-10 10ANIC-10109 HQ952541 Qd. Australia
"Diplopseustis" sp. ANIC1 AAO6767 ANICN121-10 10ANIC-10117 HQ952546 N Australia
Sufetula culshawi sp. n. ADV8747 PT NHMUK013699621 PP391030 Killearn Scotland UK
Sufetula culshawi sp. n. ADV8747 HT NHMUK014332671 PQ458043 Ibusuki Japan
Diplopseustis cf. perieresalis AAB8019 ZMBN68 LR743382 LR743405 ex. Trachycarpus C. Rica via NL
Diplopseustis cf. perieresalis AAO9850 ANICN117-10 10ANIC-10113 HQ952544 Tasmania
Diplopseustis cf. minima AAH4640 DQGM422-08 BMNH(E) #846639 PQ612424 Taiwan
Diplopseustis sp. ANIC1 AAG3100 ANICN122-10 10ANIC-10118 HQ952547 Qd. Australia
"Diplopseustis" prophetica AAO9849 ANICN120-10 10ANIC-10116 HQ952545 Australia
Musotima nitidalis AAH2841 OX421444 London United_Kingdom
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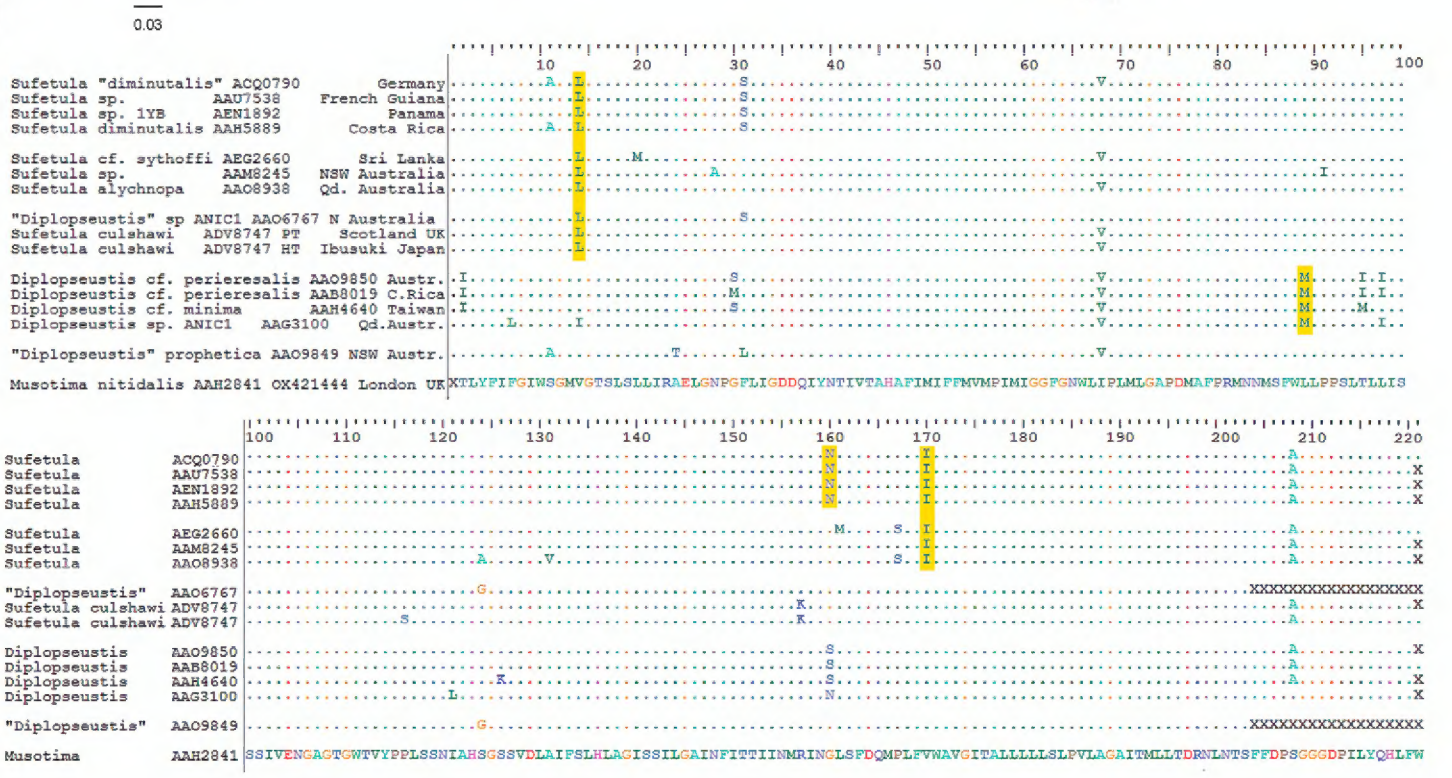
Sufetula "diminutalis" ACQ0790 Germany
Sufetula sp. AAU7538 French Guiana
Sufetula sp. 1YB AEN1892 Panama
Sufetula diminutalis AAH5889 Costa Rica
Sufetula cf. sythoffi AEG2660 Sri Lanka
Sufetula sp. AAM8245 NSW Australia
Sufetula alychnopa AAO8938 Qd. Australia
"Diplopseustis" sp ANIC1 AAO6767 N Australia
Sufetula culshawi ADV8747 PT Scotland UK
Sufetula culshawi ADV8747 HT Ibusuki Japan
Diplopseustis cf. perieresalis AAO9850 Austr.
Diplopseustis cf. perieresalis AAB8019 C.Rica
Diplopseustis cf. minima AAH4640 Taiwan
Diplopseustis sp. ANIC1 AAG3100 Qd.Austr.
"Diplopseustis" prophetica AAO9849 NSW Austr.
Musotima nitidalis AAH2841 OX421444 London UK
Sufetula "Diplopseustis" Musotima
ACQ0790 AAU7538 AEN1892 AAH5889 AEG2660 AAM8245 AAO8938 AAO6767 ADV8747 ADV8747 AAO9850 AAB8019 AAH4640 AAG3100 AAO9849 AAH2841
b

Figure 2. a. ML tree showing single cluster representatives of available DNA barcodes of Lathrotelinae on BOLD (as of 11/10/2024), showing position of *Sufetula culshawi* sp. nov. (holotype and paratype) falling basally within *Sufetula* (considered to include one "*Diplopseustis*" sp. from N Australia). Support values are ABayes from Phyml 3.0 analysis online. Seven character numbers are BIN clusters (e.g. *S. culshawi* is BOLD:ADV8747); **b.** Amino acids of the same set of Lathrotelinae plotted in Bioedit in conservation plot mode against *Musotima nitidalis* (see text); all 219 complete codons of the DNA barcode region are shown. Putative molecular synapomorphies shown in yellow highlight (subtract one for the number of complete codons; Asparagine = N; Isoleucine = I; Leucine = L; Methionine = M; Serine = S; Valine = V). Representatives of important clusters are illustrated (not to scale) and lines match them with the corresponding DNA barcode.

mm long, with variable grey, dark and white scales. Large discal black spot as in forewing but at 1/3 not 2/3. Hoary dark scaling in basal third of wing, concentrated below discal, white-bordered spot to 2/3 anal margin, almost forming itself an irregular fascia. Broad white median streak at 1/2 tapering before costal margin, bordered distad by thin relatively straight and thin dark fascia and highlighted also by white scales distad. Distal third of hindwing with intermingled brown and dark grey scales, more dark grey scales proximad. Submarginal line at similar spacing to forewing, on basal side white, black distad, in uneven scalloped pattern (with four convexities), following termen. As in forewing the area to fringe is uniformly greyer than basal parts of wings, and wider than in most *Sufetula*. Fringe mostly white at base, grey tipped, as in forewing (fringe largely worn in female, apparently accounting for the narrower gap between termen and subterminal fascia). Underside (Fig. 1b) with similar patterning but less pronounced.

Abdomen. Dark greyish (see Figs 1c, 2a on live male specimen) with prominent cream segment on tergite A2. As in other lathrotelines, tympanic organs proximally on sternum A2 proximad (Fig. 3c). Balloon-like paired tympanic bullae at proximal end of abdomen meeting at posterior origin of A2 as for other lathrotelines.

Male genitalia (Fig. 3a, b). Uncus fairly narrow but rather short, edged ventrally with proximally facing fine setae, approximately 3.5 × longer than wide. Gnathos absent. Tegumen (single arm indicated, Fig. 3a) from dorsal view widening out approaching the distad corners of the valvae. Vinculum proximad with barely a protrusion indicating a saccus, and with a transtilla-like structure just above this, reinforcing the posterior corners of the valves. Valva broad and fairly short, approximately 1.65× as long as wide; costal margin only slightly convex from the tegumen towards the apex until around half, but strongly convex up to the apex, widest in central section, distal margin tongue-like but its apex not protruding beyond the anterior margin of the valve. Costal margin curving gently and convexly towards tip of valve. Edge of entire valva with fine setae interspersed with much longer stouter setae. Juxta composed of two inwardly folded broad arms jointly forming an ovoid shape. Phallus straight, tubular, approximately 7.5 × longer than wide (excluding the manica), slightly tapering at caecum end and slightly pinched towards manica. Manica itself lacking sclerotised lamellae but with long, pointed needle-like section sitting in the sheath followed by two areas of short stout spines, followed by an area of slightly longer finer spines and culminating with a cap of long dense hair like spines.

Female genitalia (Fig. 3d). Ovipositor elongate. Papillae anales fused. Apophyses thin; apophyses posteriores slightly longer than apophyses anteriores and both moderately long. Colliculum small and triangular, slightly sclerotised at the margins and clear centrally. Ductus bursa long and slender, widening before the bursa copulatrix. Anteriorly the edges are rippled becoming straight around halfway and as it thickens it becomes ringed. Bursa copulatrix is rounded. Signa absent but one edge of bursa exhibits a prominent scobinate patch with numerous scale-like sclerotisations covering around 20% of the surface area of the bursa and on the opposite side there is a much less dense scobinate patch covering a larger area and slightly denser towards the ductus bursa opening.

Pupal exuvium. Length 7 mm, light brown, otherwise not markedly differing from the pupa of *Sufetula anania* (Solis et al. 2015).

Etymology. Named for the discoverer in Scotland, Martin Culshaw. The species epithet is a noun in the genitive case.

Distribution. Japan, Ibusuki, in the extreme south of Kyushu (type locality). Accidentally imported into Scotland (Stirlingshire, VC86), likely of horticultural origin via the Netherlands. Apparently widespread in Southeast Asia (See Referred records).

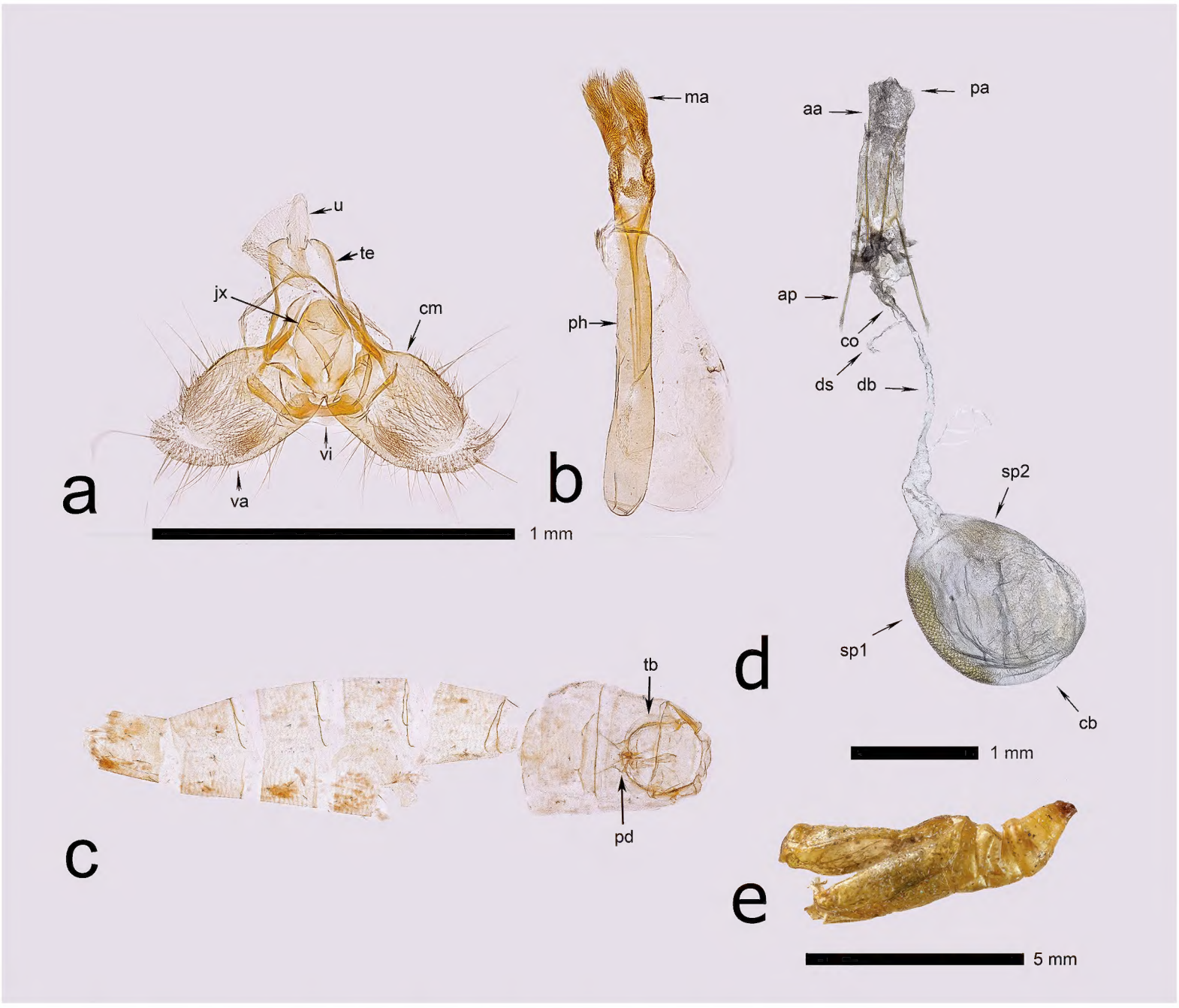

Figure 3. a. *Sufetula culshawi* paratype male, genital capsule; **b.** *S. culshawi* paratype male, phallus; **c.** *S. culshawi* paratype, male abdomen (in two parts); **d.** *S. culshawi* holotype female, genitalia; **e.** *S. culshawi* holotype female, pupal exuvium. Scalebars as shown except that phallus and abdomen are not to scale; larger part of abdomen is 4.5 mm long); va = valva; cm = costal margin; vi = vinculum; jx = juxta; te = tegumen (one of arms); u = uncus; ph = phallus ; ma = manica; tb = tympanic bulla; pd = posterior depression; pa = papillae anales; aa = apophyses anteriores; ap = apophyses posteriores; co = colliculum; db = ductus bursae; ds = ductus seminalis; sp1 = scobinate patch 1; sp2 = scobinate patch 2; cb = corpus bursae.

Biology. Living roots of Arecaceae. The Scottish specimen was found in the vicinity of two imported plants, an undetermined Araliaceae which the live moth initially flew out of, and the probable hostplant, a young multistemmed palm, confirmed as Areca Palm *Chrysalidocarpus lutescens* purchased from a nursery around May 2022, originating via horticultural trade from the Netherlands. No exuvium was detected in this case. The Japanese specimen was bred from the living roots of a palm species, likely an Areca Palm *C. lutescens* (according to our interpretation of the hostplant label) in the extreme south of Kyushu, Japan (about 31.24°N), suggesting that the species might not be native there. *C. lutescens* comes from Madagascar but is very widespread in horticulture.

Other material examined. *S. bilinealis* Hampson, 1912 (New Guinea; holotype); *S. brunnealis* Hampson, 1917 (Philippines; holotype); *S. choreutalis* (Snellen, 1879) (New Guinea, Solomon Island, New Britain); *S. chagosalis* (Fletcher, 1910) (Chagos I.; holotype); *S. cuprealis* Hampson (Borneo; holotype); *S. cyanolepis* Hampson, 1912 (Sulawesi; holotype); *S. diminutalis* (Walker, 1866) (Limas, Honduras; holotype; = *Hydrocampa dematrialis* Druce, 1896); *S. dulcinalis* (Snellen, 1899) (Central and South America); *S. hemiophthalma* (Meyrick, 1884) (Australia; = *Cangetta minuscula* Turner, 1937); *S. macropalpia* Hampson, 1899 (Papuan region; holotype); *S. minimalis* Fletcher, 1910 (Seychelles, Ghana); *S. nigrescens* Hampson, 1912 (West Africa; holotype); *S. nitidalis* Hampson, 1908 (India, Sri Lanka; holotype); *S. obliquistrialis* Hampson, 1912 (Rossel I.; holotype, ?Assam); *S. polystrialis* Hampson, 1912 (2 syntypes); *S. rectifascialis* Hampson, 1896 (Sri Lanka; holotype); *S. sunidesalis* Walker, 1859 (Malaysia, Sarawak) [see below]; *S. sufetuloides* (Hampson, 1917) (West Africa; 3 syntypes); *S. trichophysetis* Hampson, 1912 (Ghana; holotype); (Caribbean, South America); also *S.* sp. (Sud-Est Island); *S.* sp. (Nigeria); *S.* sp. (Borneo, Tahiti, Sanguir).

Remarks. The NHMUK does not certainly hold examples of the following nine species (type locality indicated): *Sufetula alychnopa* (Turner, 1908) (Australia, Queensland); *S. anania* Solis, Hayden, Sanabria, Gonzalez, Ujueta & Gulbronson, 2019 (Costa Rica); *S. boileauae* Nel, 2022 (France); *S. carbonalis* Hayden, 2013 (USA, Florida); *S. grumalis* Schaus, 1920 (Cuba); *S. hypocharopa* Dyar, 1914 (Panama); *S. hypochiralis* Dyar, 1914 (Panama); *S. melanophthalma* Hering, 1901 (Sumatra); *S. pygmaea* Hampson, 1912 (Mexico); *S. sacchari* (Seín, 1930) (Puerto Rico); *S. sufetulodes* (Hampson, 1917) (Peru); *S. sythoffi* (Snellen, 1899) (Java) [holotype is in Leiden; T. Leger, comm. pers to DL]. We could rule out *S. carbonalis*, *S. grumalis* as well as *S. sacchari* illustrated by Hayden (2013, figs 1–7). Furthermore, the species described here does not match the descriptions nor illustrations of *S. sythoffi* (Snellen, 1899), *S. melanophthalma* (Hering, 1901), *S. anania* (Solis et al. 2019). The Neotropical *S. pygmaea* from Mexico and *S. hypochiralis* from Porto Bello and the Canal zone and *S. hypocharopa* from Trinidad are much too small, according to their original descriptions (9.5–10 mm wingspan). The NHMUK has 36 specimens, likely a mixed series, currently arranged under *S. sunidesalis* and its supposed synonyms (*Mirobriga albicans* Walker, 1863, Sarawak, holotype; *Loetrina flexalis* Walker, 1863, holotype from Sarawak. NHMUK also has 12 Japanese exemplars from Ogasawara islands possibly referable to *S. minuscula* Inoue, 1996 (or an undescribed species: Y. Matsui pers. comm. to DL), but not the male holotype and paratype, which are deposited at HUS (Inoue 1966: 76, 88). Inoue (1966) states, however, that the only difference in the male genitalia from *S. sunidesalis*, which is of similar size and appearance (about 9 mm wingspan), is a more slender phallus; however, this remark was made without dissection of the primary type of *S. sunidesalis* (at OU); the specimen illustrated as such by Robinson et al. (1994: pl. 30) is in fact a larger species (ca. 17 mm wingspan) resembling the type of *L. flexalis* but unlike either *S. culshawi* or *S. sunidesalis*. There are possibly four species of *Sufetula* in the Southern Japanese islands, at least two of them undescribed, but the Japanese female from Kyushu does not resemble any of these (Y. Matsui, pers. comm. to DL).

Referred records. The following six photographs checked on 23/11/2024 are considered diagnostic for *S. culshawi* according to the possession of at least the second and third diagnostic character: *Sufetula* species, Thma Bang, Cambodia [Cardamom Mountains rain forests] (11.58, 103.128), Gerard Chartier, Jan 10, 2023 (https://www.inaturalist.org/observations/146602192); *Sufetula* species, Thma Bang, Cambodia [Cardamom Mountains rain forests] (11.580, 103.127), Gerard Chartier, Jan 18, 2023 (https://www.inaturalist.org/observations/146953865); *Sufetula* species, Cebu City, Cebu, Philippines (10.403, 123.918), Ann Lazaro, Apr 17, 2018 (https://

www.inaturalist.org/observations/11046594); *Sufetula* species, Tai Po, Hong Kong (22.418, 114.129), Artur Tomaszek, Oct 2024 (https://www.inaturalist.org/observations/248236172); *Sufetula* species, Futian District, Shenzhen, Guangdong Province, China (22.546, 114.009), J. Smith, May 21, 2022 (https://www.inaturalist.org/observations/118136868); *Sufetula* species, Aosnak, Oecussi-Ambeno, Timor-Leste [Mount Cutete Protected Area] (-9.184, 124.407), Rui Da Silva Pinto, Feb 17, 2020 (https://www.inaturalist.org/observations/38752316). The last photograph is attributed with caution to *S. culshawi*. No matching photographs were found on INaturalist on 23/11/2024 from any other region of the World.

Discussion

At the time of its initial discovery in Scotland, we considered that a new taxon might need to be described from a single male with a clearly misleading type locality, but this might no longer be the case, since the finding of a female specimen from Japan among the NHMUK accessions, which proved to be conspecific by DNA barcoding. This shows the benefit of a careful search for additional specimens in large collections in addition to a consideration of all described species. Its conspecificity would hardly have been possible to prove without DNA barcoding of the additional female specimen that showed external similarities, which was carried after the initial submission of our manuscript. This finding has now significantly expanded our knowledge of this new species.

We cannot rule out that *S. culshawi* is native to the Japanese islands, as six palm species are reported to occur there naturally (Hodel and Hsu 2013). Also, there is one endemic *Sufetula* in the Japanese islands and two or three others are undescribed there (Y. Matsui pers. comm.). *S. minuscula*, however, comes from the Oceanic pacific island of Hahajima Retto, Ogasawara islands, which lies at about 26.7°N. The Ogasawara islands include in their native flora the Chinese Fan Palm *Livistona boninensis* (Becc.) Naka, which is also widely planted outside the subtropics. *L. chinensis* var. *subglobosa* Becc. grows as far north as the southern shores of Kyushu where it occurs naturalised as a drift plant (Ehara et al. 2002). Another palm that may be native to Kyushu, or is at least naturalised there, is the Chinese Windmill Palm *Trachycarpus fortunei* (Hook.) H. Wendl; this species is particularly popular in the horticultural trade, due to its hardiness. However, that the species seems to have emerged from the same species of hostplant, a common horticultural plant, the Areca Palm (*Chrysalidocarpus lutescens*) in Japanese and Scottish cases, suggests it is more likely that the holotype specimen had been introduced to Japan, rather than colonised from the native flora. Furthermore, the diagnostically matching photographs found on INaturalist suggest the species is native to tropical Southeast Asia and widespread, possibly occurring as far south as East Timor, but no photographs of live specimens were traced from Japan or other putative regions of origin.

A few species of *Sufetula* have been confirmed as minor pests of the horticultural trade or affecting palm plantations, and observers are encouraged to check, in particular, palms that they have recently purchased as houseplants from nurseries for unfamiliar moths; also, other monocotyledons are reported as hostplants (e.g. Bromeliaceae; Solis et al. 2019). Such discoveries as this one emphasize the point that Lathrotelinae are still a strikingly poorly known group in terms of global tropical and subtropical micromoth diversity. Only a minor percentage of existing species are as yet DNA barcoded.

Our study also highlights the facts that the phylogenetics of *Sufetula* and the Lathrotelinae as a whole are very poorly known. The DNA barcode of *S. culshawi* emerged as distant in this respect from known species groupings. We interpret certain amino acid differences in lathroteline DNA barcodes as representing local synapomorphies and derived states that would confirm our generic placement. Notably, the state Methionine occurs in the 88th complete codon of the DNA barcode for 'true' *Diplopseustis*, whereas for *Sufetula*, there is a Leucine rather than Valine (or Isoleucine) in complete codon position 13. Also, a Valine for the 169th complete codon would differentiate *S. culshawi* from most so far DNA barcoded species where the state is Isoleucine. Furthermore, the combination of a Serine rather than Phenylananine in the 30th complete codon and an Asparagine rather than Guanine in the 159th complete codon appears to be a derived state for the Neotropical (but frequently exported) *S. diminutalis* species complex. The utility of these characters remains to be confirmed in a wider taxon sampling.

It is hoped that the description of this new species of *Sufetula*, with details of its male and female morphology and DNA barcode (along with the entire COI region), and likely conspecific records online, will quickly stimulate its discovery in Japan or elsewhere in East or Southeast Asia and ultimately enable clarification of its origin and hostplants.

Acknowledgements

Our thanks go to the following people who have helped us along the way: James Hayden (FDACS), Théo Léger (MfN), Anne Müller (MfN), Jacques Nel, Ole Karsholt (ZMUC), Frantisek Slamka, Colin Plant, David Agassiz (NHMUK), Mark Sterling (NHMUK) and two unnamed reviewers, who commented helpfully on the original manuscript. Our thanks go in particular to Jordan Beasley at NHMUK for sequencing a leg of the paratype male specimen, under support from Wellcome Trust funding to the Wellcome Sanger Institute (206194), and the Darwin Tree of Life Discretionary Award (218328) to the DToL consortium. We much thank Joana Cristavao (NHMUK) for processing a leg of the holotype female for Genome skimming and Ben Price (NHMUK) for bioinformatic support. Carlos Lopez-Vaamonde and Rodolphe Rougerie are thanked for use of an unpublished DNA barcode. We thank Keita Matsumoto (NHMUK) for checking our translation of the Japanese writing on the holotype data label and William Baker (RBG, Kew) for confirming the identity of the likely hostplant for the paratype male.

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Supplementary material 1

DNA barcodes

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Data type: xls

Explanatory note: **table S1.** DNA barcodes used in phylogenetic analysis in Fig. 2 and their details including accession numbers.

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